Design and Construction of a Camera System to Capture Mouse Locomotion to Assess Paw Placement and Motor Stability Affected during Chemogenetics Studies

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Introduction

A video and mechanical test fixture, as well as corresponding downstream analysis software, is being designed and developed to track paw placement of a mouse as it is forced to walk across a narrow beam or horizontal ladder. These experiments aim to quantify the effects of genetic manipulations on the ability of the mouse to maintain its gait and balance.

Background

Chemogenetics is a technique that uses drugs to activate or inhibit genetically modified neurons to provide real-time control of animal activities. The neurons are modified to express one of a variety of DREADDs (Designer Receptors Exclusively Activated by Designer Drugs). This technique has been used to manipulate neuronal activity and alter animal behavior to identify the function of neural pathways (Armbruster et al., 2007; Roth, 2016).

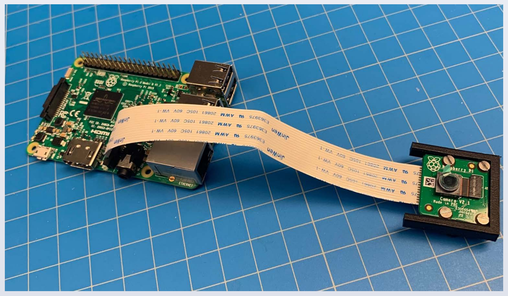
For these experiments, chemogenetic techniques will be used to investigate neural pathways that affect the gait and balance of a walking mouse. Mice, in which a targeted neural pathway has been chemo-genetically silenced, will traverse a horizontal ladder or beam. When the targeted neural pathway is silenced, a visual change in gait or balance is expected. In order to facilitate these experiments, a video acquisition enclosure and automated post-processing program is being developed to record each experimental trial and automatically identify periods where the mouse's gait is disrupted. The fixture will incorporate a set of cameras that will provide continuous monitoring of the subject from the side and from below. The post-process software will analyze each experiment's video frame-by-frame to identify the position of each paw and overall body positioning. This data can then be analyzed to determine the impact of the silencing of the targeted neural pathway.

Methods

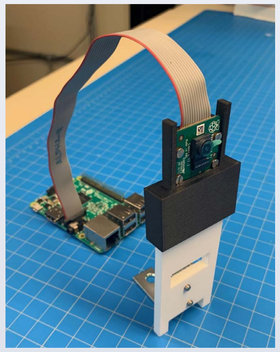
The mechanical design of this test fixture was constructed around the horizontal ladder/beam the mouse will traverse. A set of three cameras are mounted below the ladder/beam and another set are mounted along one side. All cameras are precisely positioned to enable overlapping fields of view over the length of the horizontal ladder/beam. The cameras below the ladder/beam are mounted underneath a clear plexiglass sheet to protect them from waste that might occur during an experiment.

The complete system was designed using SolidWorks, a 3D computer-aided design tool. The design is a mixture of simple laser-cut acrylic pieces and more complex 3D-printed components. The SolidWorks model incorporates both the mechanical and electrical components of the design.

Each of the six cameras are connected to a Raspberry Pi single-board computer for video acquisition and frame synchronization. The video is then streamed to a central PC for storage via a local ethernet network. Power distribution (USB hub and small PCB) and network infrastructure (router and ethernet hubs) are seamlessly incorporated in the design.



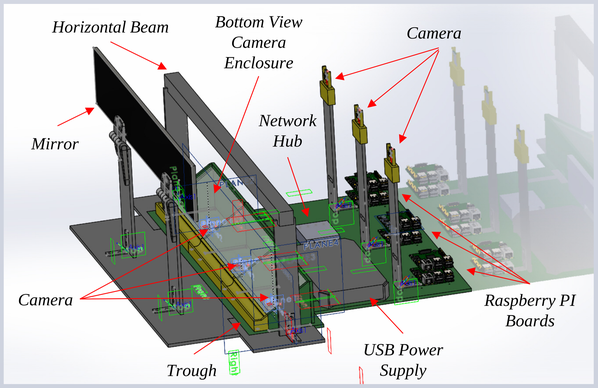
Bottom-View Camera

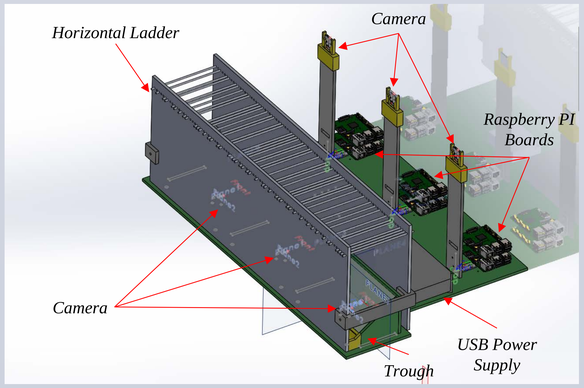


Side-View Camera

The post-processing software will stitch together video from the three bottom-view cameras and three side-view cameras. Image processing methods will be used to identify the mouse paws and estimate their position. This data will be used to identify periods where the mouse's gait was disrupted.

The components are primarily fabricated using laser-cut acrylic sections, but the more complex parts are produced using a 3D printer. The base boards, bottom-view camera enclosure, and the support structure for the side-view camera holder are fabricated using acrylic. The bottom-view and side-view camera holders, Raspberry Pi enclosures, and the waste collection system are 3D-printed.

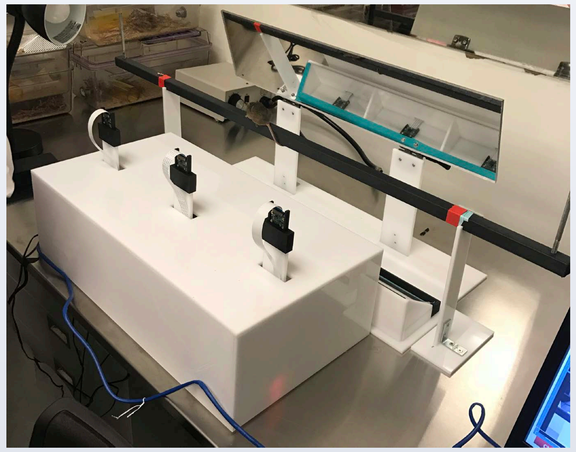




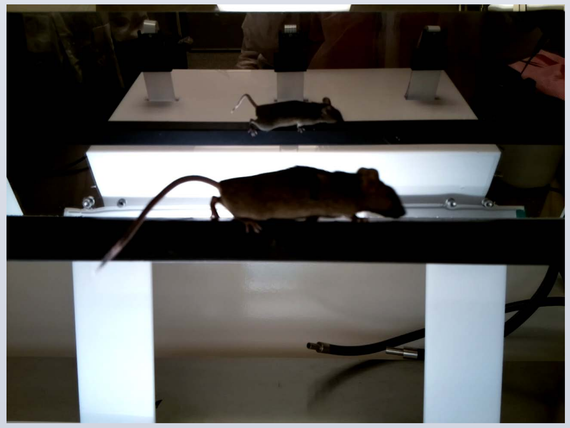
3D Model of Full System. Left: Horizontal Beam Obstacle. Right: Horizontal Ladder Obstacle

Results & Conclusion

This project is currently ongoing. The system has been designed, manufactured, and is currently being used in experiments. The next steps are to optimize the software that identifies the mouse paws. Revisions and updates to the system will be made as the applications and experiments evolve.



Complete Mouse Locomotion and Stability Monitoring System



Side View of Mouse Traversing a 1 cm Wide Balance Beam

References

Armbruster BN, Li X, Pausch MH, Herlitze S, Roth BL. Evolving the lock to fit the key to create a family of G protein-coupled receptors potently activated by an inert ligand. Proc Natl Acad Sci USA. 2007;104:5163–5168.

Roth BL. DREADDs for neuroscientists. Neuron. 2016; 89(4): 683–694.